

Gap Test Calibrations And Their Scaln

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GAP TEST CALIBRATIONS AND THEIR SCALING

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Abstract. Common tests for measuring the threshold for shock initiation are the NOL large scale gap test (LSGT) with a 50.8-mm diameter donor/gap and the expanded large scale gap test (ELSGT) with a 95.3-mm diameter donor/gap. Despite the same specifications for the explosive donor and polymethyl methacrylate (PMMA) gap in both tests, calibration of shock pressure in the gap versus distance from the donor scales by a factor of 1.75, not the 1.875 difference in their sizes. Recently reported model calculations suggest that the scaling discrepancy results from the viscoelastic properties of PMMA in combination with different methods for obtaining shock pressure. This is supported by the consistent scaling of these donors when calibrated in water-filled aquariums. Calibrations and their scaling are compared for other donors with PMMA gaps and for various donors in water.

Keywords: gap tests, shock attenuation.

PACS: 47.40.Nm.

INTRODUCTION

The most common test for measuring the threshold for shock initiation is probably the NOL (NSWC, White Oak) large scale gap test (LSGT) [1]. It consists of a 50.8-mm diameter donor of pentolite (50/50 PETN/TNT) pressed at 1.56 g/cc (91% TMD), a polymethyl methacrylate (PMMA) attenuator or gap of the same diameter, a confined sample or acceptor, and a witness plate. The acceptor was doubled in size for the expanded large scale gap test (ELSGT) [2] to examine explosives with larger critical diameter. The donor and gap were enlarged by 1.875 times to 95.3-mm diameter, the same as that for the acceptor. Because the donor in both tests has a length to diameter ratio (L/D) of 1, it is pressed as two pellets to maintain uniform density. Another variation of the larger donor, referred to as a composite donor [3], is to initiate a LSGT donor in contact with one ELSGT pellet to reduce the donor mass, which slightly increases L/D to 1.03. The effective portion of the donor, a cone from the

detonator to the donor/gap interface, is preserved, thereby maintaining the shock input of an ELSGT donor. There is a modified ELSGT (MELSGT) at Eglin AFB with the only change being a donor explosive of Composition B cast at 1.68 g/cc (97% TMD) and the addition of a 25.4-mm diameter by 25.4-mm high booster of Composition A-5, which increases L/D to 1.27 [4]. For energetic materials with even larger critical diameter, an 8-inch diameter gap test [4] was developed at Eglin AFB that evolved into the super large scale gap test (SLSGT) [5]. The SLSGT has a 203.2-mm diameter by 203.2-mm high donor of Composition B, which is boosted by the combination of the same Composition A-5 pellet in the MELSGT and a 50.8-mm diameter by 50.8-mm high cylinder of cast Composition B that increases L/D to 1.38. All tests, except the now unused 8-inch diameter gap test, have the similarity of an unconfined donor against a PMMA attenuator gap of the same diameter.

The LSGT donor has also been used in water-filled aquariums to eliminate many of the lateral

rarefactions that reduce shock duration in the acceptor [6,7]. Other pentolite donors have also been calibrated in aquariums to show the effects of L/D and scale.

CALIBRATIONS AND THEIR COMPARISON

All calibrations of shock pressure in the gap (P_G) versus distance from the donor (x) measure either the particle velocity (U_P) directly or shock position versus time, which is differentiated for shock velocity (U_S). The unmeasured velocity is obtained from the PMMA Hugoniot, and then $P_G = \rho_o U_P U_S$ is computed where ρ_o is the 1.185 g/cc density of PMMA. The LSGT calibration [8] was based on U_P measurements from electromagnetic velocity gauges. Other calibrations were obtained by measuring shock position on the attenuator axis. A streak camera was used in the ELSGT calibration [9] and piezoelectric pins were used in the MELSGT [4] and SLSGT [5] calibrations.

The NSWG calibrations for the LSGT and ELSGT use a PMMA Hugoniot that is different than the one for the Eglin AFB calibrations of the MELSGT and SLSGT. Figure 1 illustrates that there is a significant difference below $U_P = 0.5$ mm/ μ s ($P_G = 2.0$ GPa) where they are equal and a gradual separation thereafter with a 2% difference at $U_P = 2.0$ mm/ μ s ($P_G = 13.63$ GPa in the NSWG calibrations versus 13.34 GPa in the Eglin AFB calibrations). Recalculating the SLSGT calibration using the PMMA Hugoniot in the NSWG calibrations results in only small differences on the scale of the following plots for P_G versus x , despite the significant effect for $P_G < 2.0$ GPa.

LSGT, ELSGT, and MELSGT calibrations are compared in Fig. 2 over the available range of x . Because of their geometric similarity, P_G in the ELSGT should be the same as in the LSGT with x increased by the 1.875 scale of the donors. As shown in Fig. 2, however, the ELSGT data is best scaled by $x * 1.75$. Since the ELSGT calibration is limited to 100 mm, the scaled data is useful to obtain P_G in tests at up to 175 mm. The MELSGT calibration was best fitted with distances scaled by 1.875 (actual donor dimensions) and P_G in the LSGT scaled by 1.25. The pressure scaling is higher than the estimated ratio of 1.13 for detonation pressure in Composition B versus

pentolite donors. An L/D of 1.27 reduces shock curvature and lengthens shock duration, which may increase the pressure scaling.

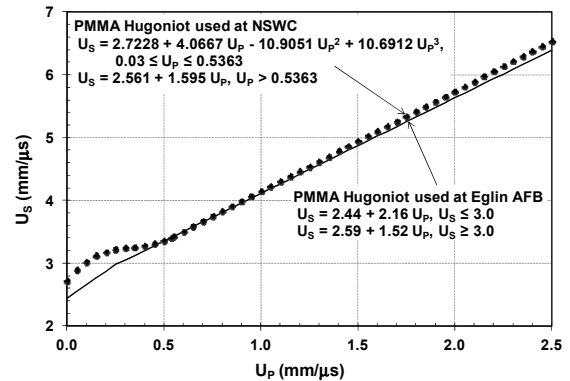


Figure 1. PMMA Hugoniot used in NSWG and Eglin AFB gap test calibrations.

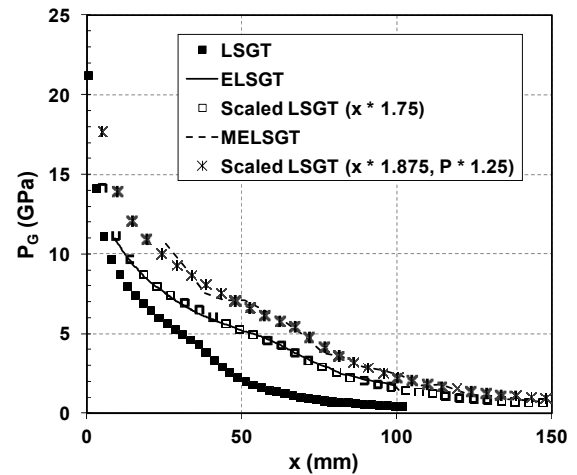


Figure 2. Comparison of LSGT and expanded donor calibrations.

The SLSGT calibration in Fig. 3 is best fit with distance in the LSGT calibration scaled by 3.75, instead of the factor of 4 in actual dimension; and P_G increased by 1.2 times for the Composition B donor, which is closer to the ratio of detonation pressure for these donors. The differences in P_G for all calibrations are compared in Fig. 4 for a non-dimensional gap thickness (x /donor diameter). While the pentolite donor calibrations are similar, P_G for MELSGT is higher than the SLSGT.

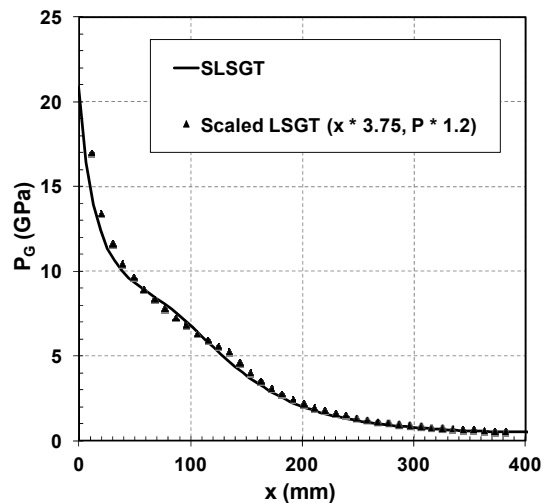


Figure 3. SLSGT donor calibration.

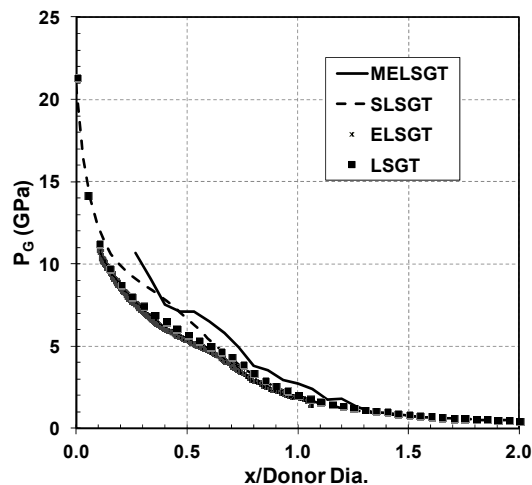


Figure 4. Comparison of all donor calibrations with a non-dimensional gap thickness.

Pentolite donors have also been calibrated in a water-filled aquarium, initially for the LSGT donor [5]. Calibrations for the LSGT, ELSGT, and composite donors, along with a single ELSGT pellet, were obtained at NSWC, White Oak from streak camera measurements of shock position versus time. Those measurements were differentiated to obtain U_s by applying a quadratic fit to a small section of data and then sliding to the next datum for a similar fit over a mostly overlapping section. U_p was computed with the Hugoniot of Rice and Walsh [10]. Calibrations for the LSGT

[11] and ELSGT donors in water are shown in Fig. 5 along with a 1.875 scaling of x for the LSGT calibration that is indistinguishable from the ELSGT calibration. The composite donor calibration is also indistinguishable from that for the ELSGT. The calibration for a single ELSGT pellet [11] follows that for the LSGT until the cusp at $x = 36$ mm associated with the arrival of the first lateral rarefaction on axis; thereafter, P_G declines at a slower rate because of the absence of these rarefactions.

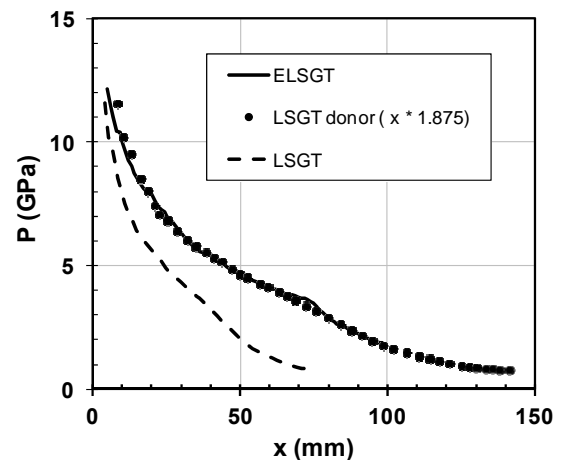


Figure 5. Comparison of LSGT and ELSGT donors in water-filled aquariums.

Bernecker, et al. [11,12] have reported on modeling axial and radial pressure profiles in the gap. They showed [11] good agreement with the LSGT calibration, slightly higher P_G for the ELSGT calibration, and equivalence for shock attenuation in a PMMA gap from composite and ELSGT donors. Sutherland [13] recently suggested that improving the viscoelastic constitutive relationship for PMMA may improve the accuracy of modeling the LSGT and ELSGT.

SUMMARY AND CONCLUSIONS

The calibration of attenuation in PMMA gaps has been compared for donors of the same diameter ranging from 50.8 to 203.2 mm, and calibration in water has been compared for various pentolite donors. To a first approximation, these calibrations can be scaled based on the size and detonation

pressure of the donor. There is a small difference in the distance scaling of the LSGT and ELSGT that may be related to the viscoelastic properties of PMMA and whether U_S or U_P was measured.

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